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THE 1972 TYPHOON ANALOG PROGRAM (TYFOON - 72)

by

CDR JERRY D. JARRELL, USN

and

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JANUARY 1973

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ABSTRACT

TYFOON, an analog program for the prediction of tropical cyclones in the western North Pacific Ocean, has been in operational use at FWC/JTWC Guam since August 1970. A brief review of TYFOON is presented focussing on its concept, operational results and limitations. Modifications to remedy shortcomings and limitations in the original version are discussed.

The modified program TYFOON-72 resulted in the reduction of both computer run time and data storage requirements. Testing and development of the modified program using a sample of 131 forecast situations are reported. TYFOON-72 compared favorably with the official JTWC and TYFOON forecasts at 24 and 48 hr and was superior to both at 72 hr.

1. INTRODUCTION

In recent years several investigators have developed statistical techniques to forecast the movement of tropical cyclones utilizing analog methods. Hope and Neumann (1970) were instrumental in the development of the HURRAN (hurricane analog) program used at the National Hurricane Center in Miami, while Hodge and McKay (1970) developed a similar but independent technique for the Navy Weather Research Facility (NWRF). More recently Gupta and Datta (1971) have implemented an analog technique to forecast tropical cyclones in the Bay of Bengal.

The HURRAN program has been used operationally since 1970 with much success (see Simpson, 1971 and Neumann and Hope, 1972). The original NWRF program was never used on an operational basis. Instead, after testing by the NWRF personnel using data from the Fleet Weather Central/Joint Typhoon Warning Center in Guam (FWC/JTWC), several modifications were made (Jarrell and Somervell, 1970), and the technique, named TYFOON, went into operational use at the FWC/JTWC in August, 1970. Like its counterpart in the Atlantic, TYFOON proved to be very successful, exhibiting average errors for the 24-, 48-, and 72-hr forecasts comparable to the official FWC/JTWC forecast errors (FWC/JTWC, 1970, 1971). In addition, the spatial distribution of the selected analog storms in terms of probability ellipses proved to be an invaluable forecast aid.

But, even with its success as a forecast tool, the originators and the operational users of the TYFOON program realized that it had several weaknesses which if corrected could further increase the accuracy of the computed forecast. The purpose of this paper is to discuss the above mentioned weaknesses and to describe the modifications which were implemented in an attempt to eliminate or reduce their effect.

To avoid confusion throughout this discussion, the name TYFOON refers to the first operational version of the NWRF analog program while TYFOON-72 refers to the latest version containing modifications discussed herein. A review of the mechanics of the TYFOON program is presented in order to gain an appreciation for the limitations discussed in later sections.

2. REVIEW OF "TYFOON"

TYFOON, like most analog schemes designed to forecast the movement of tropical cyclones, is based on finding past storms which exhibit characteristics similar to those of the storm under consideration. Some of the characteristics used in the TYFOON program are geographical location, day of year, speed and direction of movement for the past 12-, 18-, 24-, and 48-hr periods, maximum wind, minimum sea-level pressure, etc. Data for all tropical cyclones which have occurred in the western North Pacific Ocean and South China Sea during the 25-yr period 1945-69 are contained on magnetic tape. These data consist of 21 parameters for each 6-hr position during the lifetime of each tropical cyclone as outlined in Table 1. Those parameters denoted by an asterisk (*) are referred to as critical parameters since they must be specified for the current storm.

Obviously very few analog tracks would be located if the search for parameters were constrained to be exactly the value of the specified critical parameters. To get around this problem an acceptance range is defined for the critical parameters (Table 2).

To execute the program an input card containing the critical parameters and as many of the optional parameters as available is read into the computer. Ranges about the critical parameters are then computed using the criteria in Table 2. A systematic search of the historical file is initiated consisting

Table 1. Parameters contained on magnetic tape for each 6-hr position of the tropical storms and typhoons which occurred in the western North Pacific or South China Sea between 1945-69. An asterisk (*) denotes critical parameters.

Parameter	Units
*Julian date	
*Latitude	Nearest tenth of degree
*Longitude	Nearest tenth of degree
*12-hr direction of movement	Nearest degree
*12-hr speed of movement	Nearest knot
18-hr direction of movement	Nearest degree
18-hr speed of movement	Nearest knot
24-hr direction of movement	Nearest degree
24-hr speed of movement	Nearest knot
48-hr direction of movement	Nearest degree
48-hr speed of movement	Nearest knot
Radius of outer closed isobar	Nearest degree
12-hr change of radius	Nearest degree
Sea-level pressure (minimum)	Nearest millibar
12-hr change of min. SLP	Nearest millibar
Maximum wind speed	Nearest 5 knots
Minimum 700-mb height	Nearest decameter
Latitude of 700-mb ridge to north	Nearest degree
Height of 700-mb ridge to north	Nearest decameter
Longitude of 700-mb trough to the west at 35 N	Nearest degree
Height of 700-mb trough at 35 N	Nearest decameter

Table 2. Acceptance ranges for critical parameters.

Parameter	Range
Julian date	± 35 days
Latitude	± 3 degrees
Longitude	± 4.5 degrees
12-hr movement	Distance between 12-hr past position for current storm and 12-hr past position of analog after translation is ≤ 1.0 degree latitude

of a comparison of the current storm's critical parameters to those of each 6-hr position of each storm on the history tape. If any critical parameter on the tape falls outside its acceptable range it is rejected. When the search is completed a set of points which satisfy the space, time and velocity criteria are obtained. A schematic example of these data for Typhoon A is illustrated in Figure 1(a).

If an individual analog storm contributes more than one point to the set of data, these points are ranked according to their similarity to the existing storm using the similarity index defined by:

$$S.I. = \Sigma W_i \left| P_{ic} - P_{ia} \right|, \tag{1}$$

where W_i is the weight factor associated with the ith parameter, P_{ic} is the value of the ith parameter of the current storm, and P_{ia} is the value of the ith parameter of the analog position. The W_i values were specified by the originators of the program using "educated guesses" for each parameter. Only the "best" position (position which has the lowest similarity index) is retained. Next, the 24-, 48-, and 72-hr positions downtrack from each <u>best</u> analog point are computed as illustrated in Figure 1(b). Some tracks may not exist 48 or 72 hr after the best analog position; then only the 24-hr position will go into the sample.

Each of the remaining analog positions are translated to the position of the current storm as illustrated in Figure 2.

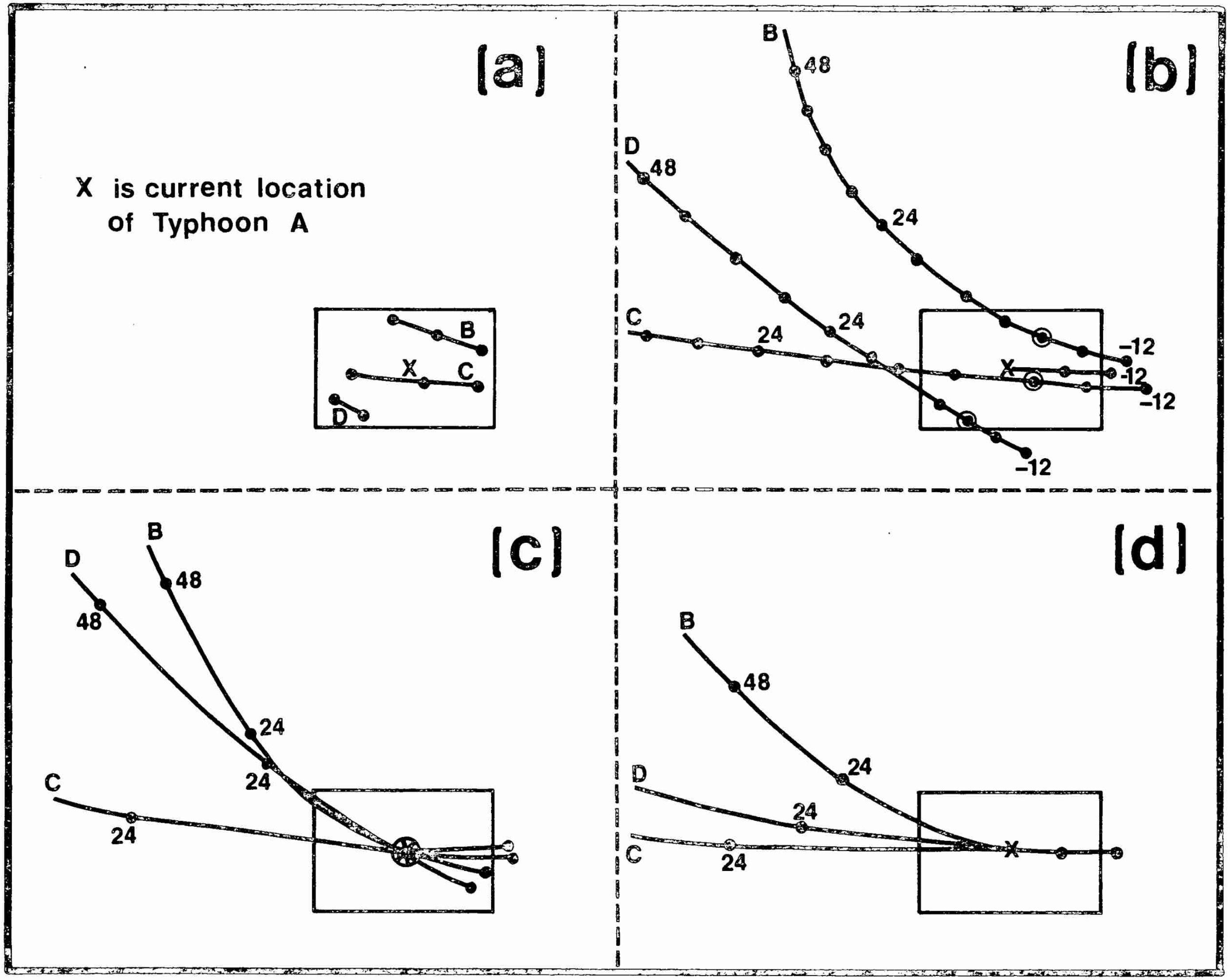

Figure 1. Schematic illustration of the stages of the analog procedure for Typhoon A which shows: (a) Positions falling within space-time-velocity envelope for analog storms B, C, and D; (b) Analog positions based on best analog position for each of the three analog storms; (c) Translation adjustment; and (d) Bias adjustment.

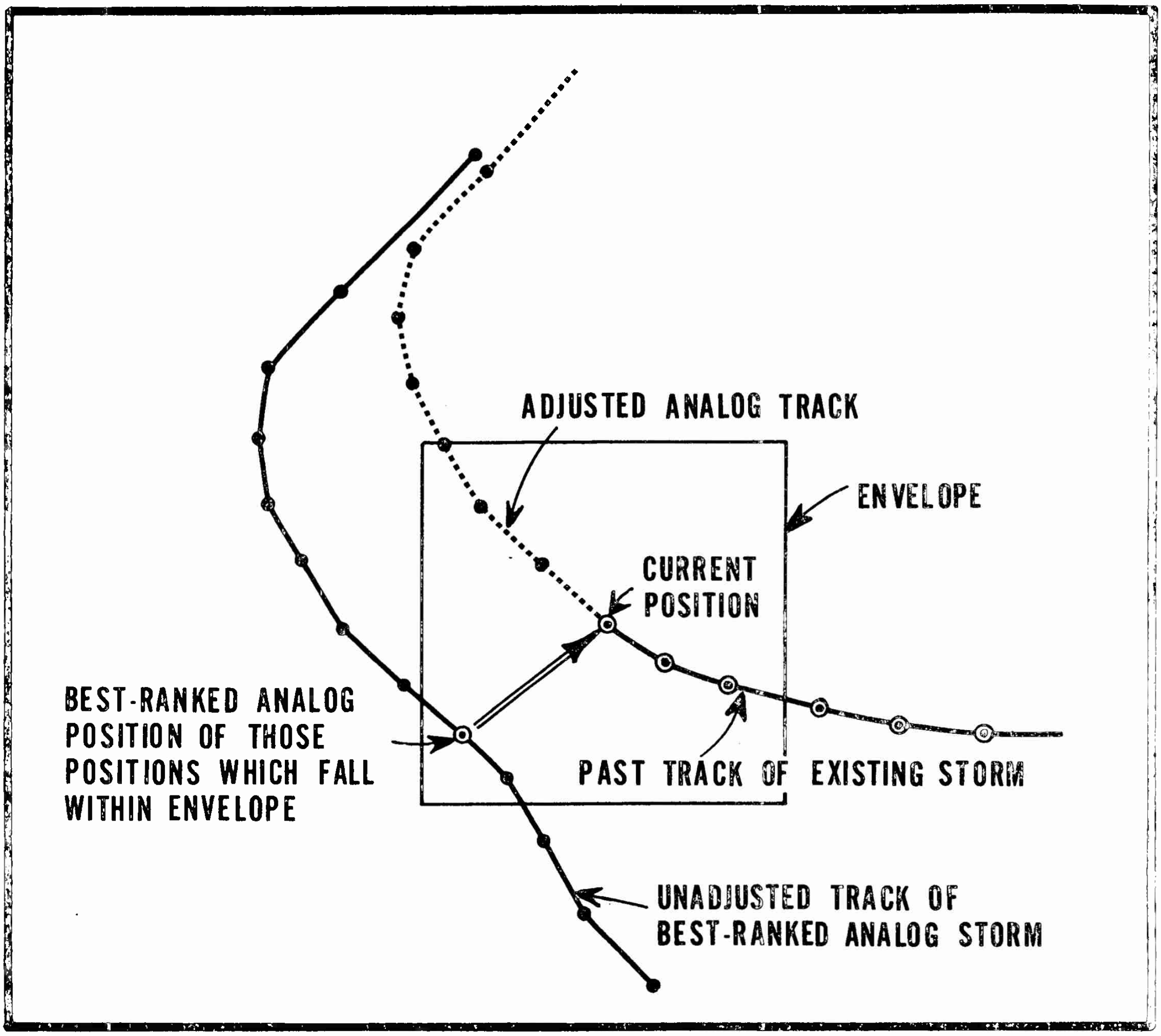

Figure 2. Example of an analog track adjusted by translation so that best-ranked analog position coincides with the current position of an existing storm.

This vector displacement is then added to all points along the corresponding storm track. Thus every analog track is initially co-located with the current storm. Figure 1(c) shows the set of analog tracks for the example storm after translation.

If the current storm and the analog are initially moving in appreciably different directions and/or speeds then the subsequent deviation between their tracks generally increases with time. To reduce the growth of this deviation with time an adjustment (or "bias") is made to the analog positions which is proportional to the vector difference between the initial velocity vector of the current storm and that of the analog storm. This procedure is illustrated in Figure 3. The vector $\vec{B}$ is the vector difference between the 12-hr velocity of the current storm and the analog storm. A value of $2\vec{B}$, $4\vec{B}$, and $6\vec{B}$ is added to the 24-, 48-, and 72-hr analog positions, respectively. The final set of analog tracks (adjusted for both translation and bias) for Typhoon A is shown in Figure 1(d).

The final phase of the forecast technique involves the computation of weighted mean positions for the 24-, 48-, and 72-hr forecasts. Each analog storm is ranked according to the similarity index discussed previously so that the storm with the <u>lowest</u> S.I. will have the highest rank (Rank = 1) and the storm with the highest S.I. will have the lowest rank (Rank = N = number of analogs being ranked). These ranks are then used to find the weighted mean latitude and longitude for each forecast time.

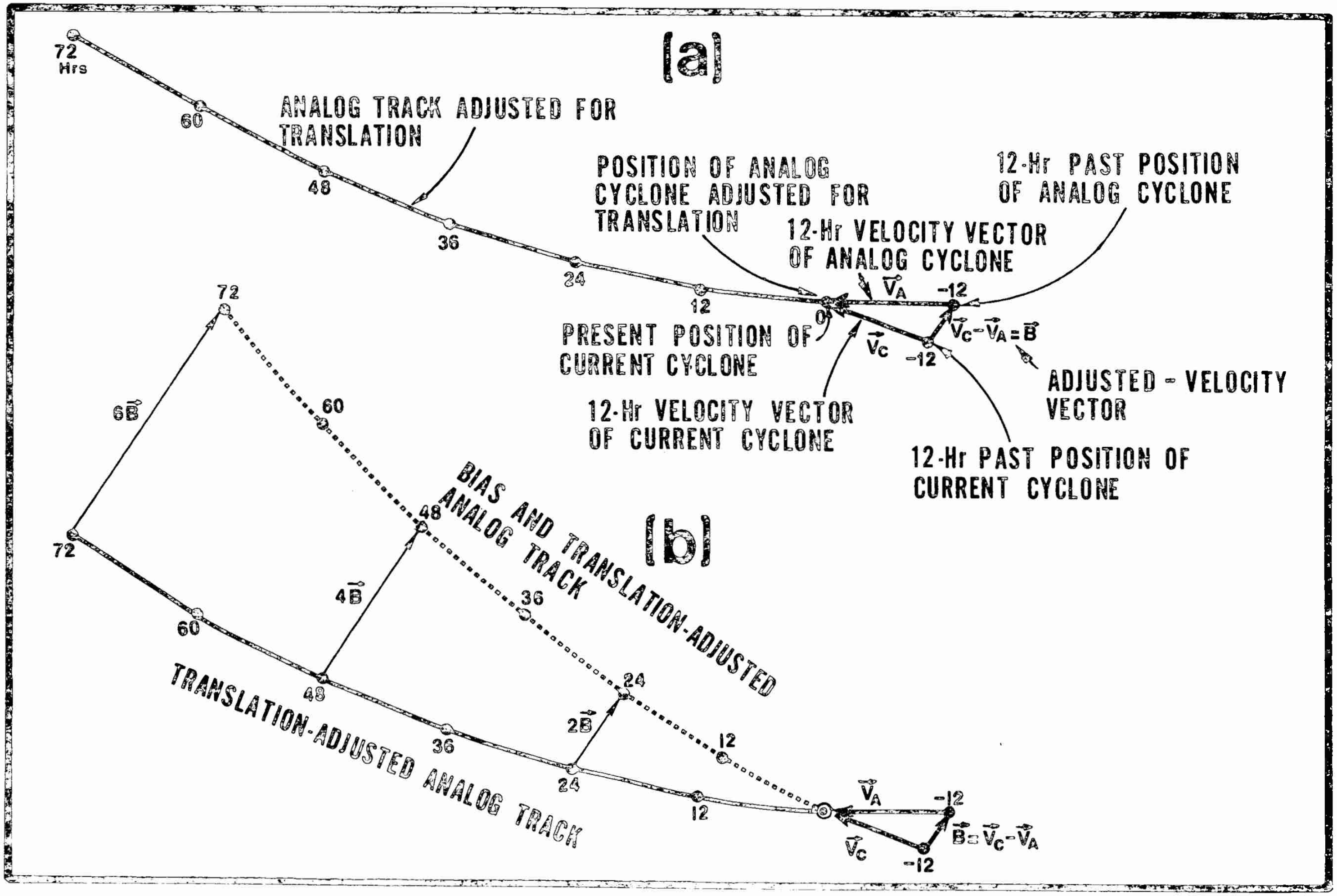

Figure 3. Velocity-difference vector (bias) adjustment: (a) Obtaining the "adjustment-velocity vector" $\vec{B}$; and (b) Obtaining the bias-adjusted position for different times.

Using the set of adjusted analog tracks, a position which is 24 hr beyond the initial position is located for each analog track in the sample. The result will be a set of latitude values and a set of longitude values for all of the 24-hr positions. A weighted mean for each set is computed as follows:

$$\text{Weighted Mean Latitude (24 hrs)} = \frac{\sum_{i=1}^{N} [N-(\text{Rank})_i+1]\,[\text{Latitude}]_i}{\tfrac{1}{2}N(N+1)}, \qquad (2)$$

$$\text{Weighted Mean Longitude (24 hrs)} = \frac{\sum_{i=1}^{N} [N-(\text{Rank})_i+1]\,[\text{Longitude}]_i}{\tfrac{1}{2}N(N+1)}, \qquad (3)$$

where N is number of ranked analogs, $(\text{Rank})_i$ is the rank of the ith ranked analog, and $[\text{Latitude}]_i$ and $[\text{Longitude}]_i$ are the adjusted latitude and longitude, respectively, of the ith ranked analog. This procedure is repeated for the 48- and 72-hr forecasts.

Finally, using the means and the standard deviations of the weighted latitudes and longitudes and the correlation coefficients between them, probability ellipses are computed for each forecast time. The final product of the TYFOON program is shown in Figure 4.

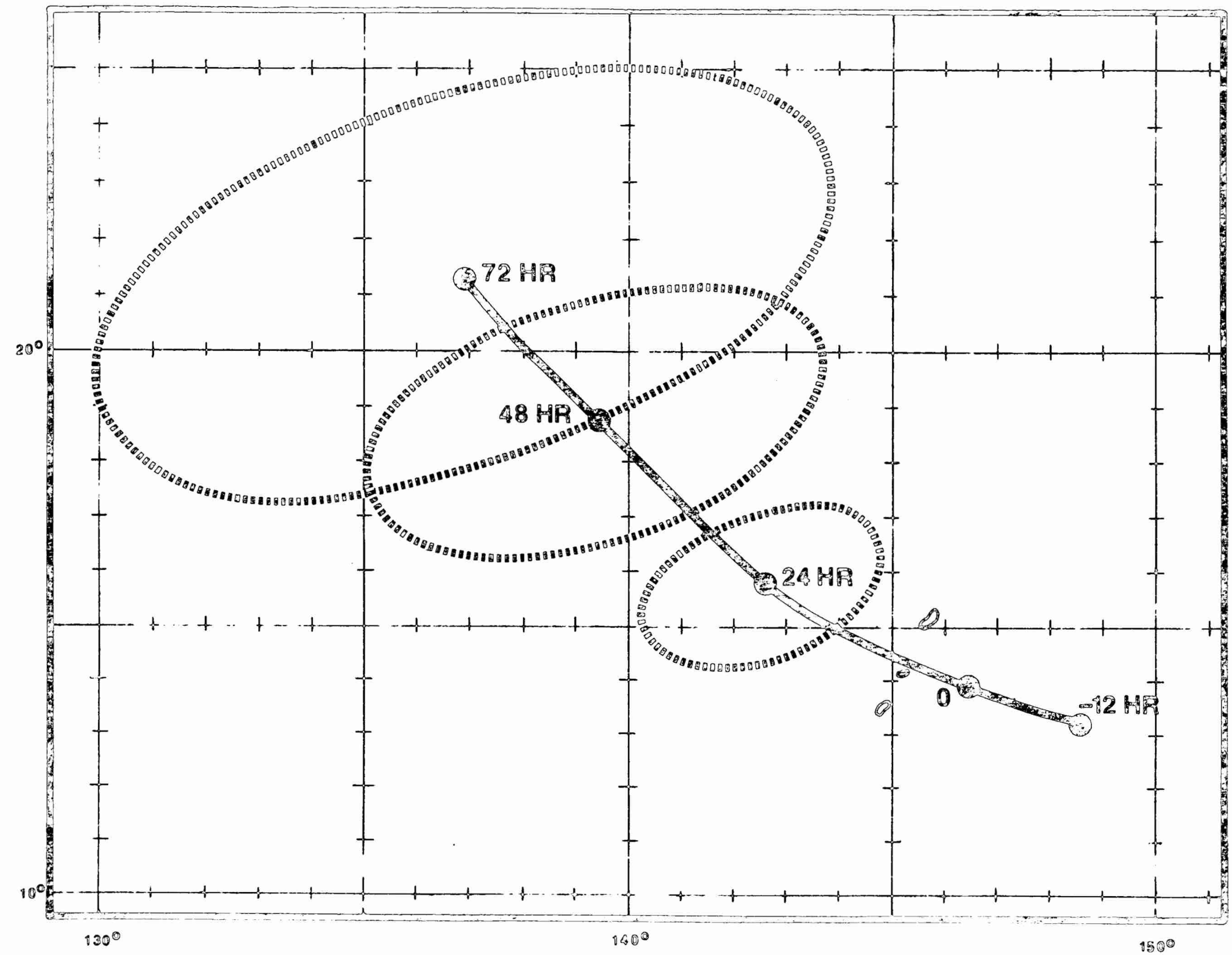

Figure 4. TYFOON forecasts showing the 24-, 48-, and 72-hr weighted mean positions and corresponding 50% probability ellipses (25% and 90% ellipses can also be provided).

3. LIMITATIONS OF "TYFOON"

As mentioned in the first section, the TYFOON program has several drawbacks despite the fact that it turned out to be the most accurate objective technique available to the forecaster. In this section these limitations are described in greater detail.

A primary problem was the excessive time required to complete a forecast for one storm -- up to 15 minutes of CDC 3100 computer time. Most of this time was involved in input-output processes, not in actual computations. The method of reading the data file was cumbersome and time consuming largely because the data on the history tape were written in an inefficient format. Frequently the FWC/JTWC had the responsibility for forecasting for two or three tropical cyclones simultaneously. The excessive time per run heavily taxed the operational computer center under these conditions. It was possible to obtain one run in a timely manner but forecasts for the second and third storms were often delayed beyond the time of issuance for the official forecast. Some means of streamlining the I/O procedures in the program were badly needed.

Computer storage had historically posed a problem in the original development of TYFOON. The concept of ranking and the early requirement to print out analog storms in order of rank required that all storms be saved during a run. Only after all storms had been examined was it possible to determine relative rank. Storing the data from all analog candidates for a single run taxed the storage capacity of the UNIVAC 1107 at NWRF, thereby limiting runs to a single storm. This same limitation prohibited multiple-storm runs operationally on the CDC 3100 computer at Guam.

During the development stage this limitation was particularily troublesome since it virtually prohibited making a statistically significant number of runs under varying conditions to tune certain critical parameters. Thus, testing was limited and several parameters were admittedly "first guesses". The success of TYFOON attests to the virtue of these guesses, but nonetheless there doubtless was room for improvement.

A particularly troublesome drawback of the TYFOON program concerned forecasts for storms which were approaching land. When the history tape was constructed only the JTWC analysis positions were included. Since warnings terminated shortly after the storms made landfall, much of the track segments taken by the storms after landfall were not included.

For example, Figure 5 schematically shows a set of analog tracks selected for the forecast of Typhoon B nearing the China mainland. The solid portion of the tracks depict the positions which are on the history tape while the dotted portions represent the tracks taken by the persisting disturbances which were either extratropical or too weak to concern the warning center. Notice that although many of the storms persist and move far into the continent, the history file gives the impression that the storms dissipated completely a short distance inland. As

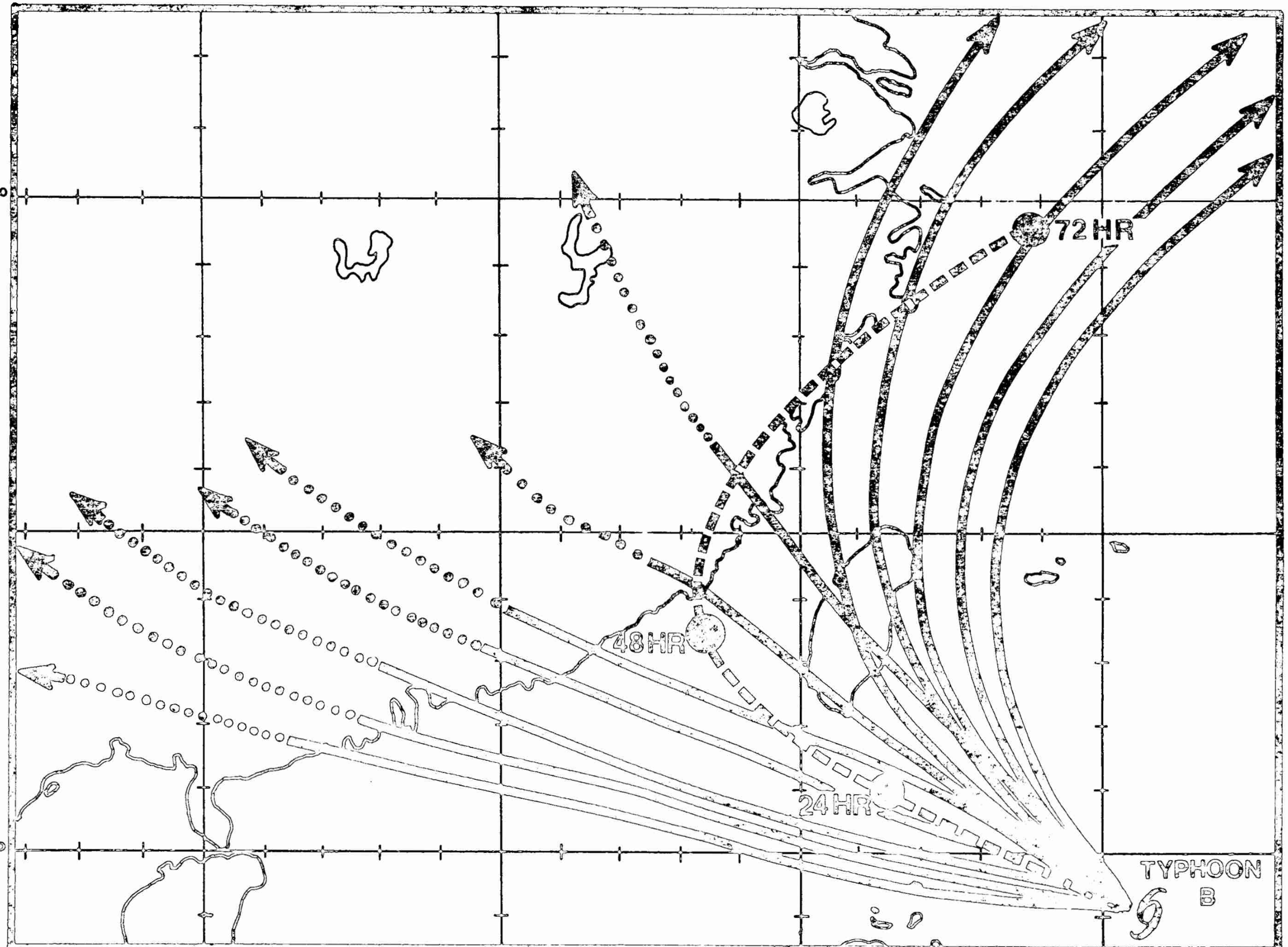

Figure 5. Schematic illustration of land bias in the analog forecast procedure.

a result the only analog positions available for inclusion into the long range forecasts are those associated with recurving storms over water east of the mainland. The heavy dashed line indicates the TYFOON forecast generated from the solid analog tracks. It is obvious that a bias exists toward the recurving tracks in this situation.

A bias also exists for recurved tropical cyclones, since in many situations the faster moving recurvers will become extratropical and will not be present on the history file. Thus, a bias will exist toward the slower moving storms or the nonrecurvers.

A matter of concern to the operational users of the TYFOON program was the use of "first guess" values for the critical parameters. As mentioned earlier this was the result of inadequate testing and development of the original program caused by severe restrictions imposed by the excessive run-time and storage problems associated with the technique. It was obvious that the values used were fairly good because of the success of the TYFOON program as a forecast tool; however, the haunting question still remained: How much better would the forecast be if optimum values (derived by statistical means) were used?

Similar concern centered on the choice of the weighting factors used in equation (1). Were the relative weights properly chosen? Could the forecast be improved by using statistically-derived optimum values for the weight factors? Some experimentation was done on individual forecasts to try to measure the effects of changing values of the weight factors, but no significance could be assigned to any observed change because of the small samples. A complete statistical analysis using a large sample was needed to determine optimum values for the weight factors.

Finally, the question of using rank as a weight factor (Eqs. (2) and (3)) in compositing the analog positions was unresolved. Testing at NWRF (Jarrell and Sommervell, 1970) indicated that the ranking process had only modest skill in selecting tracks which behaved significantly similar to the existing storm. Perhaps some other method of weighting the latitude and longitude values would produce a smaller mean error.

4. MODIFICATIONS TO "TYFOON"

Several major modifications were performed on the TYFOON program in response to the shortcomings described above. Time required to physically read the history tape was drastically reduced by rebuilding the tape in a format which allowed large blocks of records to be read rapidly prior to checking the critical parameters associated with each record.[1]

The storage problem was reduced by abandoning the concept of printing out the analog storms and further by replacing the storm rank by the similarity index (defined earlier). Thus, each analog candidate was subjected to the screening tests on critical parameters to check if they fell within set limits about the existing storm. Of those accepted, only the positions 24, 48 and 72 hours hence, adjusted for translation and bias, were retained together with the similarity index. This index was used, as discussed later, as a weighting factor for subsequent compositing of all 24-, 48-, and 72-hr positions into a single forecast at those times.

This procedure used considerably less storage space and permitted up to 30 simultaneous forecasts for a single reading of the history tape. The final operational version retained the top five ranked analogs for printout. The maximum number of simultaneous runs was set at five which was adjudged adequate for virtually any operational situation.

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[1]Card and tape input formats are given in the appendix.

A serious problem discussed earlier related to the lack of analog positions on the history tape over the Asian landmass and similarly at northern latitudes where storms have been "dropped" from warning status because they have become extratropical. As these lines of discontinuity are approached, the possible analog candidates become increasingly limited to only those which do not cross the "line", or haven't as yet. Thus, a strong bias away from the "line" is introduced. This bias becomes increasingly more important with longer range forecasts (48 and 72 hours). In order to partially counterbalance this problem, each analog track is artificially extrapolated. Since storms after recurvature are included, at which time they are typically increasing in speed, it is necessary to use a second order extrapolation polynomial. To retain realistic velocities extrapolation is limited to not more than 24 hours.

The 24-hr extrapolation greatly reduced this bias along the lines of discontinuity but extensions of the tracks from a historical map series would probably be a superior long run solution to this particular problem.

The above modifications opened the door for further testing and development of the TYFOON program because the stumbling blocks associated with time and storage limitations of the computer had effectively been eliminated.

A sample of 131 forecast situations was selected from the FWC/JTWC records from the 1971 typhoon season (this represents all available 1971 runs). The input data for each of these situations was precisely that which was available to the forecaster at the time the forecast was made. In other words none of the late information which typically goes into a detailed postanalysis of a tropical cyclone was used. This was done in an effort to include the various unknowns which exist at forecast time in the development. This resulted in a program which was optimized under actual conditions rather than using post-analysis data.

The 131 cases were randomly divided into 2 groups containing 64 and 67 cases. One group (67 cases) was used for development while the other (64 cases) was retained for testing of the final modified form of the TYFOON program (TYFOON-72). Since a TYFOON forecast had been made for all of the 131 cases, a comparison of the TYFOON, TYFOON-72, and FWC/JTWC official forecasts could be made.

Optimization of the acceptance region for each critical parameter was performed using the following approach. Limits for n-1 of the critical parameters were fixed while the acceptance limits around the remaining parameter was varied over a wide range. A TYFOON forecast was computed based on all analogs which passed the screening determined by each limit assigned to the parameter being tested. The assigned limiting value which resulted in the lowest mean error for all forecasts was selected as optimum. This derived value was then adopted as a fixed value and one of the other n-1 parameters was selected for testing. This continued until all parameters had been subjected to the testing procedure and an optimum limiting value had been derived for each one.

To make this procedure more clear, consider the optimization of the past 12-hr movement. Fixed limits were assigned to all other parameters and the magnitude of the vector between the position of the analog at minus 12 hr (following translation) and the position of the current storm at minus 12 hr was computed for each storm and subjected to various acceptance values ranging from 0.2 degrees latitude to 2.0 degrees latitude. A value of 1.8 degrees latitude was selected as a compromise value after comparing results for 24-, 48-, and 72-hr forecasts (see Fig. 6(a)).

Two points regarding the optimization procedure need mentioning here. First, even with the large reduction in computer time required for one TYFOON forecast it was still impossible to compute more than 30 forecasts per test because of operational time restrictions imposed on the FWC/JTWC computer. Twenty to thirty forecasts were considered to be an acceptable sample size for inferring meaningful estimates of the true population values for the critical parameters. Secondly, when the optimum limits of a given parameter for 24, 48, and 72 hrs varied significantly, more weight was given to the longer range forecasts in determining a compromise value.

Figure 6 shows the results of the various tests. The mean forecast error in most cases is high for small limits around

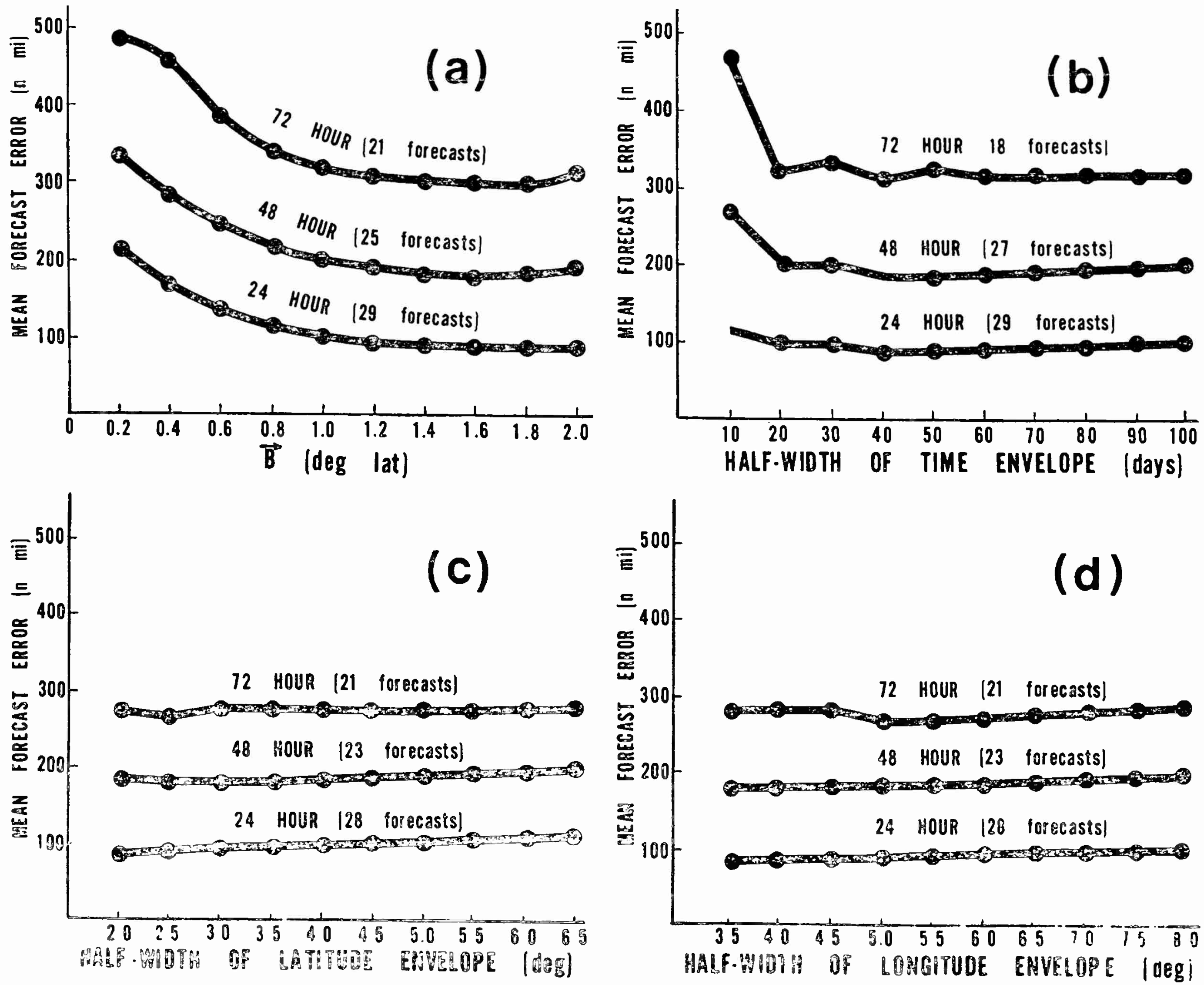

Figure 6. Mean forecast errors as a function of variations of: (a) the velocity difference vector as defined in Fig. 3; (b) the time envelope; (c) the latitudinal envelope; and (d) the longitudinal envelope.

any given parameter since the narrow acceptance range results in small samples with widely fluctuating values. As the limits around the parameter increase, a larger and larger sample results and the mean error first decreases then begins to stabilize. If the parameter limit is increased to still larger values a slight increase in the mean error occurs as more and more unrepresentative storms are included in the sample.

A similar procedure was performed on the time-growth of the bias vector which is added to the analog forecasts. The results, shown in Figure 7, indicates that the entire bias vector (100%), should be added to all forecasts out to 72 hr. This is precisely the value used as a first guess in the original TYFOON program; however, it does not agree with the test results presented by Hope and Neumann (1970) which indicated that the persistence factor used in the HURRAN program should be dropped at 36 hr. It is not known if this disagreement is a result of different testing criteria, different forms of the persistence factor, or a real difference between the movement of Atlantic hurricanes and Pacific typhoons. Perhaps it is a combination of all three factors.

Table 3 summarizes the final limits determined for each critical parameter and the growth rate of the bias vector. The original limits around these parameters are also included for comparison.

The method of assigning weighting factors to differences between the matched parameters is perhaps the most significant

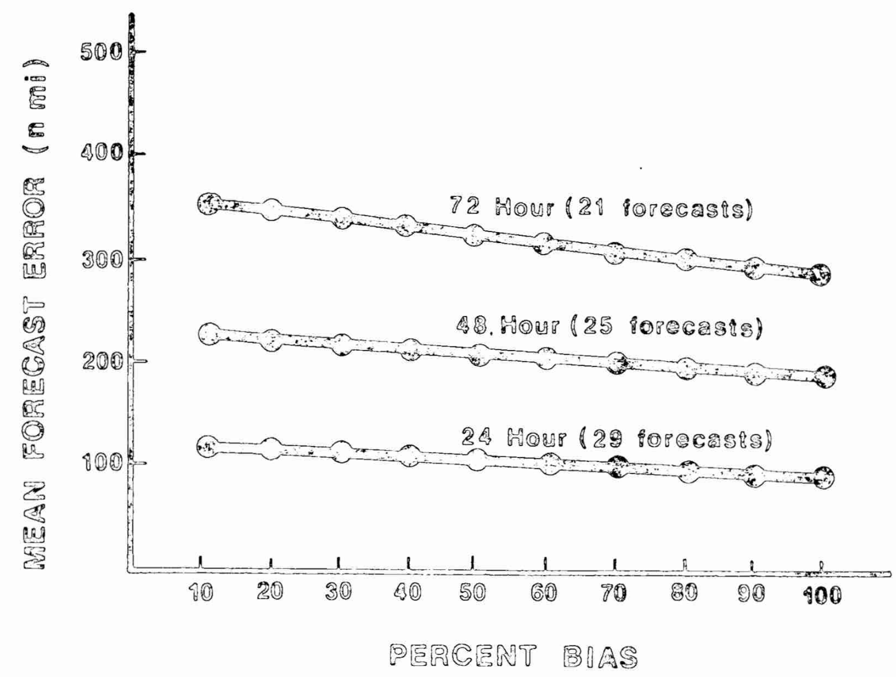

Figure 7. Mean forecast errors as a function of percent of bias added to forecast.

Table 3. Summary of derived limits around critical parameters.

Parameter	New Limit	Old Limit
Velocity-difference vector	± 1.8 deg lat	± 1.0 deg lat
Time envelope	± 50 days	± 35 days
Latitude envelope	± 2.5 deg	± 3.0 deg
Longitude envelope	± 5.0 deg	± 4.5 deg
Percent Bias	100%	100%

conceptual deviation from the original TYFOON. Originally, the absolute value of the differences was taken as an index of dissimilarity and consequently as an indication of divergent future behavior. The more recent attitude was that the sign of the difference might be important. For example, if ridge height to the north of the storm is higher than that associated with an analog storm, the existing storm probably would have a larger westward component of motion and a smaller northward component. Therefore, it appears reasonable that part of these differences in movement might be predictable from the differences in the matched parameter pairs. Thus, a least squares regression was run on the differences in parameter pairs as predictors, and the differences in the analog candidate positions and the actual verifying positions of the test storms as predictands.[1] In all, six sets of coefficients were derived, one set for longitude deviation and one for latitude

[1]To facilitate regression analysis, some parameters were redefined (i.e., S-N and W-E past displacements replaced past direction and speed) and all parameters were normalized (see appendix).

deviation, each for 24, 48, and 72 hr. These predicted deviations were then applied as adjustments to the analog positions prior to compositing.

The concept of a weighted composite track of all analogs had shown slight, though consistent, improvement over an ordinary average in the earlier TYFOON Program. That program had used rank as a measure of the relative weight assigned to each analog. Statistically the weighting process would be more effective if the weights were inversely proportional to the magnitude of the deviation between the analog track and the actual track being forecast. Also, compositing in general is more successful if the number of analog candidates is large. Earlier work in determining settings for critical values had shown that errors tended to vary with differences between these critical values, thus indicating that these differences were themselves predictors of the magnitude of deviation between tracks. To exploit this, a second least squares regression was run to predict the magnitude of deviations. The predictors used for this caluclation were the displacement from the time-space center in days, degrees latitude and longitude, the two components of bias correction, and the magnitude of the components of deviation previously computed. This predicted magnitude of deviation was then used as the basis for weighting the analogs into a composite track. The actual weighting factor was the reciprocal of this predicted magnitude of deviation.

The number of analogs was increased by treating each 6-hr position of an analog as a separate candidate if it passed the screen applied to the critical parameters. All attempts to isolate the best position failed to demonstrate any significant skill, leaving little reason for a preference among them. This change increased the number of candidates by roughly a factor of five but may have generated some bias into the sample composition. For example, slow moving storms and storms moving west along the longer dimension of the space envelope may tend to dominate the sample. It should be noted that this change was incorporated before the two sets of regression coefficients were determined.

5. SUMMARY OF RESULTS

A determined effort was made to retain all desirable qualities of TYFOON while reducing its more prominent weaknesses. Operational use of the program will be the real test of how successful these efforts were.

The major problem of excessive running time was successfully brought to within tolerable limits. Current running time is about four minutes for one storm with two added minutes for each additional storm. This compares with 10-15 minutes for each storm under the earlier program. (Running times for either program vary with season, being somewhat longer in the peak typhoon months when analog candidates are plentiful.)

The earlier version found insufficient storms for a complete forecast out to 72 hr about 25% of the time, while the current version suffers from this failure about 5% of the time. This is due solely to the extra points "dummied in" by extrapolation and the overall increase in time-space envelope dimensions. An arbitrary base minimum of five analog storms has been used as a cutoff for sufficiency in both programs.

The control group of 64 actual 1971 forecasts were rerun, using TYFOON-72. The forecast errors were compared with actual errors in the official forecasts issued by the JTWC and errors made by the original TYFOON. Of the 64 forecasts, 63 could be verified at 24 hr, 55 at 48 hr and 42 at 72 hr. Forecasts by the JTWC and the earlier TYFOON fell off drastically in sample size at longer ranges. Part of this was due to the Pacific Command policy of requiring 48- and 72-hr forecasts only on named storms and 72-hr forecasts only at 12-hr intervals instead of 6-hourly. The resulting low sample sizes for homogeneous comparison weakens the statistical validity of the results, but differences in long-range forecasts still appear meaningful. Table 4 presents comparisons of 24-, 48-, and 72-hr average forecast errors by both the JTWC and the earlier TYFOON, contrasted against TYFOON-72.

For the 24-hr forecast it is difficult to do better than the official forecast. Further, it is evident that the current TYFOON is no improvement over the earlier version in the 24-hr time frame. It should be pointed out that preference was always shown for longer range forecasts in the critical parameter portion of the TYFOON-72 development. At longer ranges the superiority of TYFOON-72 over the older model becomes more evident in that a reduction in the average error of over 10% is evident at both 48 hr and 72 hr with a shift in ratio of relatively superior forecasts from 1:1 at 24 hr to 2:1 at 72 hr. Notice that at 48 and 72 hr TYFOON-72 appears to compare quite well with the official JTWC forecasts (homogeneous samples), although the small sample size deters any great degree of confidence in such a comparison. The averages for all TYFOON-72 forecasts at 48 and 72 hr are based on fairly large numbers and are certainly very credible.

All forecast techniques are sensitive to the accuracy of the initial position, and this is particularly true for the

Table 4. Comparison of average forecast errors (24-, 48-, and 72-hr forecast errors in n mi) for the control group of 64 cases. The sample size is given in parentheses.

	24-HOUR AVERAGE ERRORS			
	JTWC/TYFOON-72		TYFOON/TYFOON-72	
Same Forecasts (homogeneous)	103(60)	107(60)	106(56)	106(56)
% Superior Fcsts	53	47	50	50
All Forecasts	103(60)	107(63)	106(56)	107(63)
	48-HOUR AVERAGE ERRORS			
Same Forecasts (homogeneous)	185(43)	191(43)	203(47)	180(47)
% Superior Fcsts	46	54	45	55
All Forecasts	185(43)	188(55)	203(47)	188(55)
	72-HOUR AVERAGE ERRORS			
Same Forecasts (homogeneous)	328(17)	285(17)	282(33)	251(33)
% Superior Fcsts	29	71	33	67
All Forecasts	328(17)	258(42)	282(33)	258(42)

TYFOON series. With limited airborne reconnaissance in WESTPAC, the problem of a poor initial position has become commonplace. This is a severe limitiation on TYFOON since multiples of the bias correction vector are added to climatological positions. Hence, the initial position error tends to persist and grow linearly with time in the forecasts. TYFOON-72 was not designed to accommodate a poor initial position; however, it does have a design feature which might be exploited when the initial position is in doubt. The bias correction can be avoided by providing insufficient data for the computation of bias; in particular, the past 12-hr position could be entered as missing (-99, -99). This results in a forecast that is little more than climatology. Since TYFOON 72 can accommodate up to 5 simultaneous forecasts, it is suggested that runs be made with and without 12-hr history for comparison purposes, with the possibility of merging the forecasts according to confidence in the initial position.

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APPENDIX

HISTORY FILE TAPE AND CONTROL CARD FORMATS

HISTORY FILE TAPE FORMAT

Each logical record contains N+1 physical records

Physical Record 1

Item		Binary Words
1	Number of observations this storm (N)	1
2	First Julian date of this storm	1
3	Last Julian date of this storm	1
4	Name of storm	2
5	Storm month-year-sequence number	1

Physical Records 2 to N+1, one for each 6-hourly observation, 22 words each

Item	
1	Zulu date-time-group
2	Julian date
3	Latitude (in tenths of degrees)
4	Longitude (in tenths of degrees)

18 NORMALIZED PARAMETERS** (dimensionless)

		MEAN	STD DEV
*5	Past 12-hr S-N movement	1.10 deg	1.09 deg
*6	Past 12-hr W-E movement	-0.73 deg	1.95 deg
*7	Past 18-hr S-N movement	1.63 deg	1.56 deg
*8	Past 18-hr W-E movement	-1.13 deg	2.82 deg
*9	Past 24-hr S-N movement	2.15 deg	1.99 deg
*10	Past 24-hr W-E movement	-1.56 deg	3.59 deg
*11	Past 48-hr S-N movement	4.14 deg	3.37 deg
*12	Past 48-hr W-E movement	-3.43 deg	6.23 deg
13	Size, radius of outer closed isobar	4.31 deg	1.89 deg
14	12-hr change in size	0.15 deg	0.84 deg
15	Minimum sea-level pressure	979.11 mb	22.88 mb
16	12-hr min SLP change	-0.36 mb	14.94 mb
17	Maximum sustained wind	65.56 kt	32.12 kt
18	Minimum 700-mb height	2908.0 m	250.9 m
*19	700-mb ridge location deg N of storm	10.12 deg	4.15 deg
20	700-mb height at ridgeline N of storm	3143.2 m	37.9 m
*21	700-mb trough location deg W of storm	13.69 deg	10.84 deg
22	700-mb height at trough and 35N	3074.0 m	48.4 m

*These parameters are redefined from the original TYFOON history file.
**Normalized parameter values are 100x(parameter-mean)/Std Dev, and 999 is missing.

CONTROL CARD FORMAT

COLUMN	NAME	VALUE	COMMENT
1	NC	3	Control function.
*2-3	IMO	01-12	Month.
*4-5	IDA	01-31	Day.
*6-7	IHR	01-24	Hour.
*8-10	ILAT	001-500	Latitude, degrees and tenths.
*11-14	ILON	0001-1800	Longitude, degrees and tenths.
**15-17	JPUT(1)	001-500	12-hr latitude, degree and tenths.
**18-21	JPUT(2)	0001-1800	12-hr longitude, degrees and tenths.
22-24	JPUT(3)	001-500	18-hr latitude, degrees and tenths.
25-28	JPUT(4)	0001-1800	18-hr longitude, degrees and tenths.
29-31	JPUT(5)	001-500	24-hr latitude, degrees and tenths.
32-35	JPUT(6)	0001-1800	24-hr longitude, degrees and tenths.
36-38	JPUT(7)	001-500	48-hr latitude, degrees and tenths.
39-42	JPUT(8)	0001-1800	48-hr longitude, degrees and tenths.
43-45	JPUT(9)	000-999	Size, radius of storm in degrees.
46-48	JPUT(10)	000-999	12-hr change in size.
49-52	JPUT(11)	0000-9999	Minimum sea-level pressure in mbs.
53-55	JPUT(12)	000-999	12-hr change in sea-level pressure.
56-58	JPUT(13)	000-999	Maximum wind speed, kts.
59-61	JPUT(14)	000-999	Minimum 700-mb height, 10's of meters.
62-64	JPUT(15)	000-999	700-mb ridge latitude, whole degrees.
65-67	JPUT(16)	000-999	700-mb ridge height, 10's of meters.
68-70	JPUT(17)	000-999	700-mb trough longitude, whole degrees.
71-73	JPUT(18)	000-999	700-mb trough height, 10's of meters.
74-80	Optional	up to 7 characters, storm name or number.	

NOTE: Missing data are denoted by -99 right adjusted in the appropriate field.
Up to five input cards are allowed, and the last must be followed by a blank card.

*These items are required for computation of critical parameters.
**These parameters are required for computation of bias.

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13. ABSTRACT

TYFOON, an analog program for the prediction of tropical cyclones in the western North Pacific Ocean, has been in operational use at FWC/JTWC Guam since August 1970. A brief review of TYFOON is presented focussing on its concept, operational results and limitations. Modifications to remedy shortcomings and limitations in the original version are discussed.

The modified program TYFOON-72 resulted in the reduction of both computer run time and data storage requirements. Testing and development of the modified program using a sample of 131 forecast situations are reported. TYFOON-72 compared favorably with the official JTWC and TYFOON forecasts at 24 and 48 hr and was superior to both at 72 hr.

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